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# Guidelines for co-creating climate adaptation plans for fisheries and aquaculture

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## Abstract

Climate change is having a significant impact on the biology and ecology of fish stocks and aquaculture species and will affect the productivity within seafood supply chains in the future. The challenges are further amplified when actors within the fisheries and aquaculture sectors have very different ideas and assumptions about climate change and what risks and opportunities they entail. In order to address the challenges of climate change, several countries have developed national adaptation plans. However, fisheries and aquaculture are rarely included in these plans, resulting in a general lack of documented adaptation strategies within these sectors in most countries. This paper introduces guidelines for the development of climate adaptation plans (CAPs) within fisheries and aquaculture, applying a co-creation approach that requires the participation of scientists, industry representatives, policymakers, and other relevant stakeholders. The objective is to provide a stepwise approach to facilitate and enable stakeholders to plan strategies toward climate adaptation. The guidelines are based on practical experience and include a three-step process: (1) assessment of risks and opportunities; (2) identification of adaptation measures, and (3) operationalization of CAPs. The three-step process is also part of a larger cycle, including implementation, monitoring, and evaluation, again generating iterative feedback loops over time. Lessons learned are discussed, and we highlight the advantages and challenges of developing CAPs. While the guidelines are designed for and tested within fisheries and aquaculture systems, the CAP approach is also employable for other natural resource-based systems.

**Keywords** Climate change · Adaptation measures · Vulnerability · Co-creation · Sustainability

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## 1 Introduction

Climate change is altering marine and coastal environments throughout the world, with changes observed in ocean currents, rising sea levels, increasing sea temperatures, acidification, changes in rainfall, and increased severity and frequency of extreme events. These changes, in turn, are affecting fishery and aquaculture sectors, with changes in fish growth; younger age and larger size at maturity; changing fish distribution, including movement toward the poles; altered species composition in catches; reduced production and yield; and increase in diseases (Aune et al. 2018; Barange et al. 2018; Blanchet et al. 2019; IPCC 2019). The observed impacts also affect the socio-economic status of the fisheries and aquaculture sectors, such as changes in food security and income. In order to maintain responsible, sustainable, and profitable seafood production under climate change, climate adaptation strategies are needed, at a local, national, and global level (Barange et al. 2018; EC 2007; EC 2013).

Global work on the impacts of climate change on fisheries and aquaculture is still at an early stage. Although there is a relatively significant body of knowledge on the biological impacts of climate change on aquatic ecosystems, there is less knowledge on the socio-economic consequences and necessary responses (De Silva and Soto 2009). Several organizations and agencies are developing guidelines for mainstreaming adaptation measures in fisheries and aquaculture and testing and adopting a standardized methodology for assessing and documenting best practices, such as the Food and Agriculture Organization of the United Nations (FAO 2019), Worldfish (2007), and the International Fund for Agricultural Development (IFAD 2014). After the Paris Agreement was adopted in 2015, only 68 countries out of 155 included fisheries and aquaculture in their adaptation strategies when submitting nationally determined contributions (NDC) (Barange et al. 2018). Pioneering countries in developing detailed plans for climate adaptation in the seafood production sectors are the United Kingdom, the USA, Australia, and Uruguay. By 2018, 25 EU Member States (MSs) had adopted National Adaptation Strategies (NAS),<sup>1</sup> and 15 had developed National Adaptation Plans (NAPs).<sup>2</sup> However, there is limited information on whether or not these adaptation strategies and plans toward reducing vulnerability to climate change have made decisive progress. Furthermore, climate change is largely absent in the EU's main regulatory frameworks for fisheries and aquaculture, such as the Common Fisheries Policy (CFP), the Marine Strategy Framework Directive (MSFD), and the 2013 "Strategic guidelines for the sustainable development of EU aquaculture." In addition, concrete plans for an adaptation of the fisheries and aquaculture sectors are still lacking in most MSs that are dependent on fish and fisheries (EC 2018). Adaptation efforts are impeded by the lack of concrete guidance and the absence of coordinated efforts across countries (Blanchet et al. 2019), making it difficult for industry operators, policymakers, and scientists to move toward adaptation in fisheries and aquaculture. Hence, the development of guidelines on making climate adaptation plans (CAPs) to guide and support communities, sectors, and countries in their adaptation efforts is more important now than ever (Barange et al. 2018; FAO 2019; Preston et al. 2011).

<sup>1</sup> National Adaptation Strategies (NASs) address overarching climate change issues that allow them to position adaptation on the policy agenda (EC 2018).

<sup>2</sup> National Adaptation Plans (NAPs) aim to implement NASs and to organize actions for achieving their objectives, typically through sectoral implementation (EC 2018).

This paper presents guidelines that provide a practical step-by-step approach to the development of CAPs for fisheries and aquaculture. The process consists of three main tasks: (1) assess risks and opportunities; (2) identify adaptation measures; and (3) implement adaptation measures. A co-creation approach is applied that allows different stakeholders with diverse backgrounds and positions to jointly scope and plan their adaptation efforts. This co-creation approach ensures realistic and inclusive CAPs that are fully applicable to the selected sector and increase the likelihood of success.

The paper provides details on the theoretical background and approach for each step and thereby supports the recently published CEN<sup>3</sup> Workshop Agreement (CWA) voluntary standard on “Good practice recommendations for making climate adaptation plans for fisheries and aquaculture” (CEN 2020). The guidelines are discussed in the light of other existing adaptation tools, highlighting the differences between fisheries and aquaculture in the CAP development process.

## 2 Framework for developing CAPs

The CAP guidelines were developed using two main approaches: the social-ecological approach and the co-creation approach. The former was employed to identify relevant focal components of the sustainable fisheries/aquaculture system. The latter was used to determine the level of stakeholder participation in the development of CAPs. After devising a prototype, the guidelines were applied to seven different fisheries and aquaculture case studies within Europe using species from multiple trophic levels and evaluated for multiple years (Table 1). The methodology and the CAP development process were modified and improved through iterative feedback loops. The CAP guidelines also followed the standardization process devised by the European Committee for Standardization (CEN).<sup>4</sup>

To ensure that the CAP guidelines aligned with other relevant initiatives and guidance, we reviewed the main features of the adaptation processes outlined by, among others, Climate-ADAPT,<sup>5</sup> which suggests a three-stage process: (1) assess risk, opportunity, and vulnerability; (2) identify and assess adaptation measures; and (3) implement, monitor, and evaluate adaptation. There is an increasing body of literature that provides methodologies which can be applied in fisheries and aquaculture for risk assessment (e.g., Field et al. 2012; Hobday et al. 2011), vulnerability assessment (e.g., Barsley et al. 2013; Brugere et al. 2015; Johnson et al. 2016; Metcalf et al. 2015; Oppenheimer et al. 2015), and the development of adaptation measures (e.g., Grafton 2010; Watkiss et al. 2019). With the aim of achieving a more sustainable fisheries/aquaculture system based on a socio-ecological perspective and co-creation, we adopted the framework of Fletcher (2015) for risk and opportunity assessment, of Metcalf et al. (2015) for vulnerability assessment, and of Climate-ADAPT (2019) for

<sup>3</sup> A CEN workshop for developing fisheries and aquaculture CAPs was established to ensure representability and involvement of a broad set of stakeholders. Throughout this process, the guidelines were evaluated, reviewed, and revised on several occasions based on the input and feedback of the CEN workshop participants. At the end, consensus was reached, and a CEN Workshop Agreement (CWA) was established, ensuring that the guidelines will be available through national standardization bodies for at least 3 to 6 years after they were published.

<sup>4</sup> The standardization process given by the European Committee is described here: <https://www.cen.eu/work/ENdev/how/Pages/default.aspx>

<sup>5</sup> The adaptation support tools of Climate-ADAPT are available at: <https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool>

**Table 1** Characteristics of seven ClimeFish case studies that have developed CAPs

Sector	Case study	Geographic area	Species
Marine fisheries	1. Pelagic	North-East Atlantic	Norwegian spring-spawning herring, mackerel, blue whiting
Lake and pond	Demersal	West of Scotland	cod, haddock, whiting, hake, saithe
	Cold water	Italian Lake Garda	European whitefish
	Warm water	Hungary	Common carp
Marine aquaculture	North	North-East Atlantic	Atlantic salmon
	South	Greece	European seabass, meager
	Coastal	Spain, Iberian Upwelling	Mediterranean mussel

developing adaptation measures. The specific methodologies applied are included in the CAP guidelines presented in detail below. Terms and concepts used are defined in the supplementary material.

## 2.1 Socio-ecological approach

Fisheries and aquaculture are socio-ecological systems with a complex interplay of social and ecological processes (Berkas 2011; Ostrom 2009). Hence, the sustainability of fisheries and aquaculture requires appropriate consideration of the four pillars of sustainability: ecological, economic, social (including cultural), and institutional (governance) (Boström 2012; Garcia et al. 2014; Garcia and Staples 2000; Rindorf et al. 2017; Stephenson et al. 2018). These four pillars, hereafter called categories, are divided into a set of sub-categories, and then further into components (Table 2). The components were suggested based on group discussions with fishery and aquaculture experts. The components vary by case and system, depending on factors such as the nature and size of the system, interactions with other industries, and existing knowledge and data.

## 2.2 Co-creation approach: Stakeholder participation in the development of the CAP

The importance of stakeholder engagement in policy development has been well documented (Gramberger 2001). Stakeholder involvement provides a better knowledge base for policy formulation, enables the development of common visions and responsibilities, ensures compliance, increases trust in national authorities, and builds a stronger democracy. Different degrees of stakeholder participation exist, ranging from information, consultation, collaboration, and co-creation to empowerment (Luyet et al. 2012). The CAP development process employs a co-creation approach which allows stakeholders to be involved throughout the process, from the scoping phase to the implementation and the monitoring and evaluation phases. This approach enables extensive engagement with society. It generates knowledge that has scientific acceptability, policy relevance, and social robustness (Jasanoff 1990), and it facilitates the achievement of consensus (van Vliet et al. 2010). It also significantly increases participants' ownership of the process and hence the likelihood of eventual success of the CAP. As such, the co-creation approach places the CAP guidelines presented in this paper firmly in the context of recent research on policymaking, EU adaptation strategies, and policy and legislation in fisheries and aquaculture.

**Table 2** Categories, sub-categories, and components of a sustainable fisheries/aquaculture system considered for evaluation

Sustainability category	Sub-category	Component	
		Fisheries	Aquaculture
Ecological	Productivity	Catch, biomass, fishing mortality, discards, bycatch	Growth rate, biomass, survival, size, densities, feed consumption ratio
	Biodiversity	Species richness, non-native species, genetic diversity, trophic levels, evenness of the food web	Farmed escapees
	Habitat and ecosystem	Diseases and pathogens, invasive species, pollution, proportion of migration pathway, seafloor integrity, area protected, spawning areas	Diseases and pathogens, water quality, farm locations
	Business economics	Industry's profit, market price relative to the marginal cost of production	Industry's profit, feed price relative to marginal cost, infrastructures, costs for chemical use and monitoring activities
Economic	National economics	National incomes (gross value added in fisheries/aquaculture including backward linkage, forward linkage, and flow on)	
	Employment	(Un)Employment in fisheries/aquaculture, gender balance	
Social (including cultural)	Health and well-being	Proportion of fishers/farmers with average income below the poverty line; availability of affordable services (e.g., education, housing; proportion of seafood caught within the community and consumed by the locals; occupational safety (number of deaths and injuries related to the job, ranking of job safety, proportion of fisheries/aquaculture workforce subject to labor laws, and meets certification standards (e.g., first aid, emergency duties)	
	Governance structure	Structure of (national/local) administration, institutional legislation/regulation, resources dedicated to compliance and to scientific monitoring and research, agreements, international commitments, evidence of collaboration and cooperation	
Institutional (governance)	Legal obligations	Record of accountability with respect to laws and policies rules (e.g., commercial activities covered by institutional processes, evidence of support for institutional processes and/or legislation and regulation), licensing frameworks, compliance, inspections, and surveillance	

Stakeholders were selected following the typology developed by Newton and Elliott (2016). The typology proposes the range of stakeholders who should be engaged in the development process: extractors, inputters, beneficiaries, affectees, regulators, and influencers (see roles of the stakeholder types and suggested stakeholder organizations in supplementary material). To develop CAP guidelines and try them out in the seven case studies, 194 stakeholders were involved. Several of them belonged to more than one category in the Newton and Elliott (2016) typology, and for the sake of simplicity, we classified the stakeholders into four groups: (1) 79 were from various industries (extractors, inputters, beneficiaries); (2) two came from advisory bodies representing interests affected by the extractors and inputters (affectees); (3) 54 were policymakers from directorates, Member States, ministries, and local governments (regulators); and (4) 59 were from scientific bodies and NGOs (influencers). Feedback and input received from stakeholders during the development of the CAPs for the seven cases were used to improve the CAP methodology and the guidelines in an effort to enhance their efficiency and applicability to the sector. Additionally, 36 stakeholders with expertise in fisheries, aquaculture, and climate change participated in the CEN workshop to standardize the CAP guidelines.

### 3 Guidelines for developing CAPs for fisheries and aquaculture

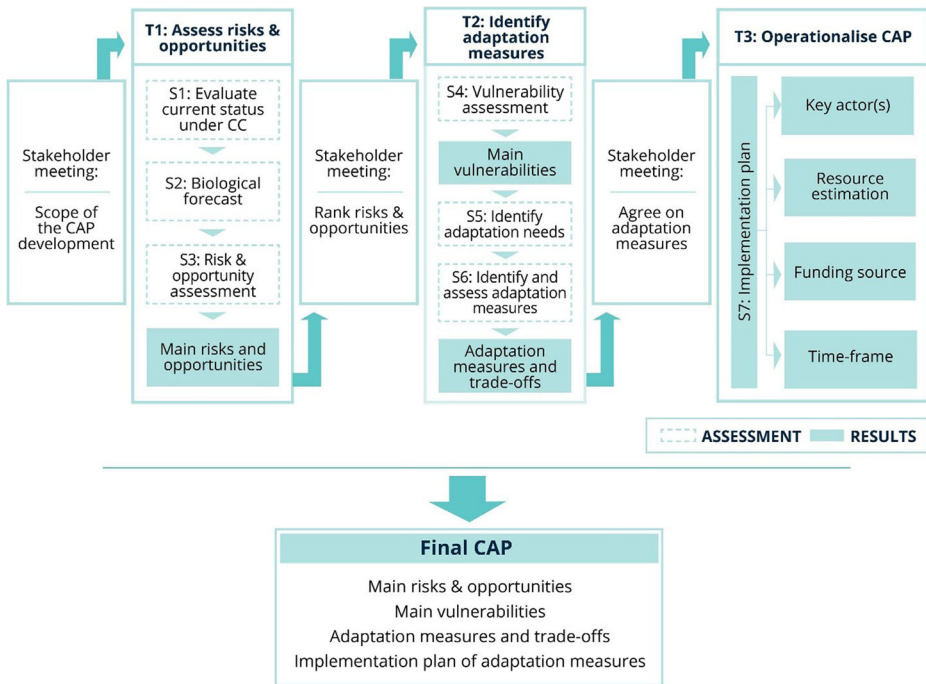
The guidelines consist of three main tasks (T1–T3): T1, assessment of risks and opportunities; T2, identification of adaptation measures; and T3, operationalization of the CAP. These tasks are conducted through seven steps (S1–S7) in conjunction with three stakeholder meetings. The tasks, steps, and stakeholder meetings are described in chronological order and detail below (Fig. 1). A finalized CAP includes details on main risks and opportunities, vulnerabilities, a set of adaptation measures (AMs) and trade-offs, and an implementation plan for all identified AMs.

#### 3.1 First stakeholder meeting: Scoping of the CAP

The first meeting aims to create a mutual understanding of the CAP development process. The process can be initiated by different actors, ranging from national authorities—e.g., ministries and other government bodies—to independent fishing/aquaculture companies. The CAP initiator takes responsibility for identifying and inviting stakeholders who are relevant to the CAP development process to participate. During the meeting, the aims and scope of the CAP must be clarified and determined to set clear objectives and frames for the CAP development process—e.g., target species, area under evaluation, and one fishery or all fisheries within that area. The main tasks and steps of the process are discussed and documented and formalized through the CAP agreement. At this first meeting, stakeholders' roles are also identified. They can either become members of the CAP consortium or join the reference group, depending on their interests. The CAP agreement is then signed by all consortium members in order to formally start the CAP development process. The tasks of the two stakeholder groups are defined as follows.

CAP consortium members are:

- Directly involved in the development of CAP throughout the process.



**Fig. 1** Flowchart of guidelines on developing a climate adaptation plan (CAP). The CAP development consists of three tasks (T1–3) and seven steps (S1–7)

- Responsible for conducting the steps of the CAP process, depending on their expertise and resources.

#### Reference group members are:

- Not directly involved in the development but interested in the CAP process.
- Informed throughout the process and consulted at relevant stages during the CAP development process.
- Invited to participate in all scheduled stakeholder meetings, at their own expense.

#### 3.1.1 Task 1 (T1): Assessment of risks and opportunities

**Step 1 (S1)—Evaluate current status and recent changes in the face of climate change** Based on the sustainability categories and the suggested components in Table 2, the CAP consortium members identify all components that are relevant for the fishery or aquaculture system under consideration. The selected components are then discussed to explore: (1) What is the current status of the component? (2) Have any recent changes been observed? (3) What climate drivers are likely to have caused the observed changes? As far as available resources allow, all views are documented and taken into account in the subsequent steps of the CAP process, to ensure that the resulting CAP will include more than one adaptation measure for each climate-related threat if needed, tailored to the needs of different stakeholder groups.



**Step 2 (S2)—Biological forecasts** The aim of biological forecasting is to provide information on changes in biological parameters under future climate change that dictate species' distribution and production. In fisheries, these parameters can be distribution, recruitment, growth, migration, phenology, and trophic interactions; for aquaculture, they can be growth performance, feeding rates, diseases, and harmful algal blooms. The selected timeframe and warming scenarios depend on the scope of the CAP but should ideally cover short-term, mid-term, and long-term timeframes, and model both RCP 4.5 (medium warming) and RCP 8.5 (worst case scenario). The modeling approaches used can range from simple empirical temperature growth models, to individual-based models and food web models, and to complex ecosystem models that include physical and biogeochemical simulation modules. The level of detail and level of acceptable error of the forecasts can differ between cases. A suitable modeling tool is chosen based on recent literature and modeling advancements. For instance, for marine fisheries, a food web ecosystem model like Ecopath with Ecosim (Serpetti et al. 2017) can be used to project not only outputs such as species biomass and catches but also a number of ecosystem indicators (Baudron et al. 2019). In the future, more traditional fisheries assessment models will be expanded to include similar ecosystem effects such as predator-prey dynamics and temperature effects (Holsman et al. 2015). Given the uncertainties associated with using just one modeling approach, an ensemble approach is likely to be more effective (Anderson et al. 2017). With respect to marine aquaculture, the dynamic energy budget theory could be applied and validated (Stavrakidis-Zachou et al. 2019) to simulate the bioenergetics of an individual as a function of temperature and food availability followed by extrapolation to the population level. The model outputs are then examined to identify the best possible fishing/farming regime(s) under different climate scenarios.

Step 2 describes how each biological component identified in S1 is likely to respond to forecasted climate change, ideally based on the outputs of the forecasting model. In cases where modeling forecasts are not an option, information on biological projection can be acquired through a detailed literature review. Even though biological forecasting is not a prerequisite for CAP development (Dessai et al. 2009), quantitative indications of the potential climate change effects on the biological components are highly beneficial for a number of reasons. Firstly, by providing quantitative results, they offer a better understanding of how severely those biological components are affected, and therefore can be used to assess risks and opportunities. By including temperature in their forecasts for Pacific cod and arrow tooth flounder of the Bering Sea, Holsman et al. (2015) estimated that recommended yields were higher in models that included temperature compared to the same models without temperature effects. Secondly, quantitative forecasting provides evidence for initial discussions between stakeholders (e.g., Dowling et al. 2020), which helps to prioritize the remainder of the CAP development process. Discussing the results of the biological forecast at this stage offers a valuable opportunity for stakeholders to express their concerns based on their own observations and experiences, some of which scientists and/or other experts might have overlooked. This can result in either a wider or a narrower scope of the final CAP. Lastly, biological forecasting allows assessment and comparison of the outcomes of candidate management scenarios (e.g., Baudron et al. 2019) designed to mitigate the impact of future climate change. Such results can then be used to inform stakeholders and help design a CAP.

**Step 3 (S3)—Ranking risks and opportunities** Climate change is closely related to risk. The concept of risk has been much discussed in recent years, and in the literature, it is pointed out that the concept must be differentiated in order to address the complex interactions and many

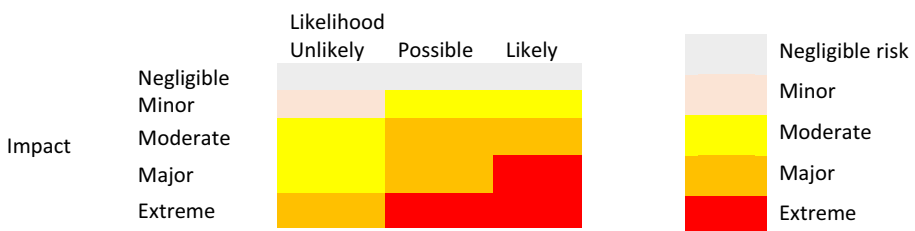


uncertainties associated with climate change (Barsley et al. 2013; Brugere et al. 2015; Field et al. 2012; Hobday et al. 2011; Oppenheimer et al. 2015). In the most common definition, the risk is defined as the function of probability and impact—that is, the likelihood that an event will occur and the consequences which that event may have. Risks provide both opportunities and threats, but in everyday speech, the risk is normally associated with threats or dangers. Particularly, when it comes to climate change, the focus is on the negative or adverse effects. Hence, in this study, we distinguish between risk and opportunity assessment and carry out both in order to identify negative and positive effects, respectively. Various assessment methods exist, the most feasible depending on factors such as data availability and level of stakeholder involvement. Here we suggest using a matrix approach where risks (Fig. 2) and opportunities (Fig. 3) are ranked based on the composition of the impact level (using a five-point scale) and the likelihood of the impacts (measured on a three-point scale). The impact levels are set as 1, negligible (not measurable); 2, minor (minimal impact); 3, moderate (some impact but no significant consequences/benefits); 4, major (large impact with large consequences/benefits); and 5, extreme/transformational (very large impact with huge consequences/benefits). Similarly, the likelihood levels of an event are set as 1, unlikely; 2, possible; and 3, likely to happen.

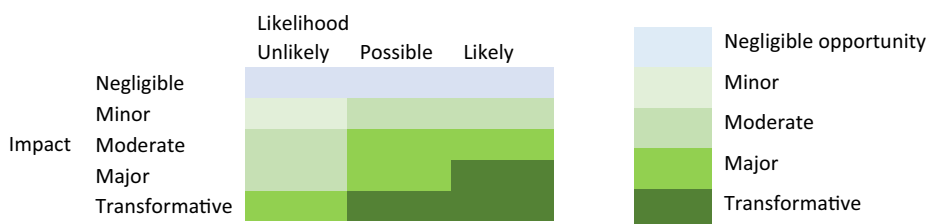
The assessment is conducted by stakeholders in the CAP consortium who have socio-economic expertise. Firstly, possible climate impacts on all components identified in S1 are described as risks or/and opportunities, taking into account the results of the biological forecasting in S2. Secondly, the severity and likelihood of the impacts are assessed based on the participants' knowledge and perceptions and by using the matrix approach outlined above. The results are shared with the stakeholders involved in the reference group during the second stakeholder meeting in order to gain their input, evaluation, and validation. Since many stakeholders are interested in quantitative information about the scope and magnitude of the possible socio-economic consequences of climate change, social and economic components should also be modeled and estimated where possible and relevant.

### 3.2 Second stakeholder meeting: Ranking risks and opportunities

The aim of the second stakeholder meeting is to gain a broad review of the assessment of risks and opportunities, including the perceptions of both the reference group and the other stakeholders. This ensures that important practical experiences and information are taken into account and interpreted properly by scientists based on the daily realities of operations familiar to stakeholders. During the meeting, the biological forecasting results from S2 and the list of climate-related impacts identified in S3 are communicated to and discussed with the



**Fig. 2** Risk-matrix approach. The impact level is on a scale of 1 to 5 (negligible, minor, moderate, major, and extreme); the likelihood level is on a scale of 1 to 3 (unlikely, possible, likely)



**Fig. 3** Opportunity-matrix approach. The impact level is on a scale of 1 to 5 (negligible, minor, moderate, major, and transformative); the likelihood level is on a scale of 1 to 3 (unlikely, possible, likely)

stakeholders, who give their opinions on the identified impacts, agree on the impacted components, and, if necessary, add new impacts to finalize the list of impacts. Then, the stakeholders define whether each impact on the final list represents a risk or an opportunity and rank the impacts based on the knowledge gathered during the meeting, using the same approach as described in S3. If new impacts are suggested, the scientists follow the same process. The overall rank of each risk and opportunity is averaged from the scores of stakeholders from both the consortium group and the reference group.

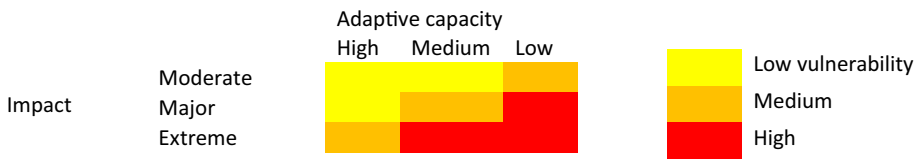
In most cases, the number of impacts identified is larger than the number that can be implemented. Therefore, it is important at this stage to prioritize components that, in the context of climate change, are associated with high risks and opportunities. Only these components will be considered during task 2.

### 3.2.1 Task 2 (T2): Identification of adaptation measures

**Step 4 (S4)—Vulnerability assessment** Measuring vulnerability is considered a prerequisite for climate change adaptation (Metcalf et al. 2015). There are different approaches for assessing vulnerability, such as through the risk hazard approach (Renn and Klinke 2015) or the sustainable livelihood approach (Scoones 1998). Barsley et al. (2013) gathered an extensive collection of experiences of vulnerability assessments in the context of fisheries and aquaculture. In the present study, a qualitative bottom-up approach based on stakeholders' perceptions was chosen for vulnerability assessment, because experience shows that quantitative methods are seldom sufficient (Barsley et al. 2013). Quantitative methods require much more data, and, in many cases, such data have to be aggregated on different scales, which might lead to inaccuracy. Furthermore, a CAP is designed for and used by stakeholders, and so the method suggested should be straightforward and fairly easy to use.

In general, central factors in determining vulnerability are impacts and the ability to tackle each impact, called adaptive capacity (AC). To measure AC, we use the capital framework designed by Scoones (1998) and adapted for fisheries by Metcalf et al. (2015). Accordingly, the AC is measured by six forms of capital: human, social, natural, physical, financial, and governance.<sup>6</sup> Furthermore, resource dependence is added to account for the levels of

<sup>6</sup> Human capital refers to the availability of skills, expertise, knowledge, and human labor to undertake livelihood activities. Financial capital refers to financial resources available to support policy measures and incentives (Gupta et al. 2010). Social capital is made up of the social bonds (e.g., family networks) that facilitate cooperative action and the social bridging through which ideas and resources are accessed. Social capital also includes rules, norms, obligations, and trust embedded in social relations, and societies' institutional arrangements. Physical capital consists of manmade goods such as roads, machinery, tools, and other input to production processes. Governance capital refers to the qualities of the governance system and authorities in terms of legitimacy, accountability, transparency, inclusion, fairness, leadership coordination, and collaboration (Lockwood et al. 2015).



**Fig. 4** Vulnerability-matrix approach. The impact level is set to be moderate, major, and extreme; the adaptive capacity is set to be high, medium, and low

employment and income derived from fisheries/aquaculture. All forms of capital are ranked by the CAP consortium members using a three-point Likert scale from low to medium to high AC, and then, the median is determined for each impact. These AC ranks are combined with the rank of impacts, which were evaluated in T1, to come up with a ranking of vulnerability. The prioritized medium and high vulnerabilities (Fig. 4) will be used further in step 5.

**Step 5 (S5)—Identification of adaptation needs** Identification of the adaptation needs of each component serves two purposes: (1) to provide a clear picture of the broad future objective for each component and (2) to suggest the direction of the adaptation needed—i.e., what is required of the AMs to effectively adapt to climate change. Stakeholder input is crucial in this step, as stakeholders will likely have a clear vision regarding the desired future scenario of the components, especially of the social and economic ones.

Adaptation needs can be identified through the simple exercise of asking stakeholders: What would the desired future scenario for this component be? Stakeholders with various backgrounds might view the desirable state of each component differently, and therefore, the adaptation need can include more than one objective. However, if the stakeholders come up with contradictory objectives, it is important to try to formulate a common objective to which all parties can agree.

It should be kept in mind that the adaptation needs for a specific component might be different when considered in terms of one impact as opposed to another. For instance, when looking at the infrastructure component within an aquaculture system, its adaptation needs toward the increased presence of pathogens (e.g., fouling prevention) will be very different than toward more extreme weather events (e.g., sturdier infrastructure). It is therefore important to consider the adaptation needs of each component under each impact.

**Step 6 (S6)—Set adaptation measures** AMs are designed to (1) help fulfill the adaptation needs and (2) reduce vulnerability and mitigate risks while utilizing potential opportunities. AMs can be divided into three levels, as shown below, aligned with three different time scales for implementation (short term, mid-term, and long term).

- Industry-level AMs can be implemented by the operators (i.e., fishermen, farmers, processing companies) independently of government decisions.
- Policy recommendations may apply to the industry level, but they are about public policy and administration and require government decisions. The recommendations can range from changes in legislation and the setup of new government agencies to financial incentives to spur climate adaptation, insurance schemes, or funding of research and technology development.
- Research and knowledge gaps include identified knowledge gaps that should be filled to facilitate climate adaptation. In many cases, while it is clear what kind of AM is needed,

the best implementation is unclear. An example of this is the need to develop breeding programs so that fish can thrive under new and challenging conditions. In this case, the identification of genes related to thermal adaptation is necessary, as traits such as environmental sensitivity and disease resistance might become new breeding goals. Therefore, industry-level AMs can be identified but research is needed before implementation.

Once a list of AMs has been identified, it should ideally enter a more detailed appraisal prior to implementation, focusing on trade-offs of the AMs (Watkiss et al. 2019). An ex-ante impact assessment based on forecasts rather than actual results is proposed since the measures have not been implemented yet and therefore cannot be evaluated. The suggested procedure for an ex-ante impact assessment of the AMs could be: (1) identify who will be impacted and (2) predict how the impact will evolve over time. Well-conducted ex-ante impact assessments can support evidence-based policymaking and facilitate discussion among stakeholders throughout the process. If possible, the AMs should be included in forecasting models to quantify their possible impacts. For those AMs that cannot be modeled, the impacts can be evaluated using a qualitative approach, where potential trade-offs between the AMs are identified and discussed, balancing the ecological, social, economic, and governance dimensions.

### 3.3 Third stakeholder meeting: Agree on adaptation measures

The AMs identified in S6 are discussed at the third stakeholder meeting. At this stage, additional stakeholders who are familiar with the fishery/aquaculture system in question are still welcome to join the reference group and participate in the meeting. This allows validation of the results from the meeting, avoiding extreme opinions, and updating information that might be lacking during the second meeting. Stakeholders are encouraged to express their opinions on the feasibility of the AMs. A set of AMs agreed by the majority of stakeholders is the expected outcome of this meeting.

#### 3.3.1 Task 3 (T3): Operationalization of CAPs

**Step 7 (S7)—Implementation of adaptation measures** This step evaluates the work effort required and describes prerequisites for the implementation of the AMs. The main items to consider in planning this step are key actors, resource estimates, potential funding sources, and timeframes.

**Key actors** Before implementing AMs, it is important to identify which key actor(s) will be responsible for which AM. There is always at least one default actor responsible for one measure—i.e., the industry operators in question for industry-level measures, policymakers or government agencies for policy level measures, and scientists for research-level measures. More than one actor can be responsible for the implementation of certain AMs.

**Resource estimation** The estimated resources needed for implementing an AM must be evaluated at this stage, as resources can easily become a major constraint. The estimation should include all aspects of implementation and operation and should be made in consultation with the actors involved in each AM. Where possible, a cost-benefit analysis should be carried out.

**Source of funding** The availability of funding is crucial for the implementation of different AMs. Various sources should be explored, ranging from private funding from stakeholders and companies, to national and European research funds and international funding bodies, such as the European Maritime and Fisheries Fund (EMFF) or the LIFE program, the EU's funding instrument for the environment and climate action. Such funding sources can include funds with high eligibility criteria as well as funds that are more accessible for small, less institutionalized organizations with modest climate change project experience. The funding sources do not need to be confirmed at this stage, but an overview of potential contributors and options should be provided.

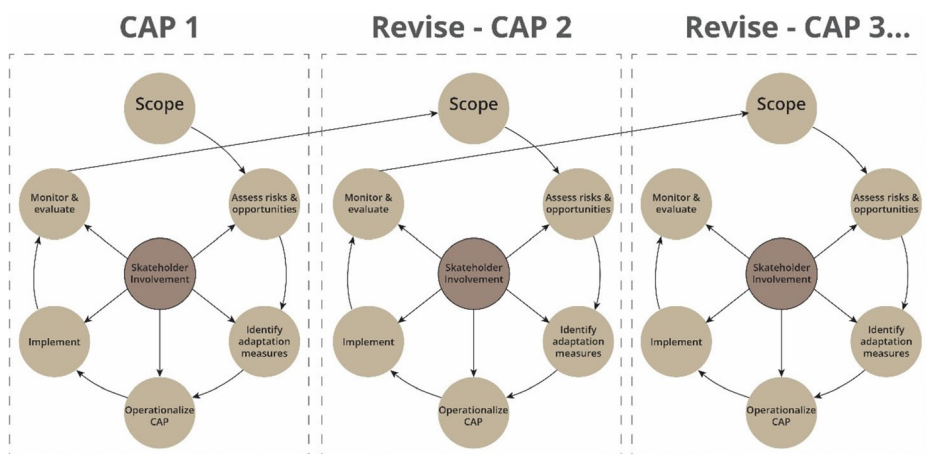
**Timeframe** The timeframe refers to the time needed for planning and implementation of the AMs. The timeframe must be seen in the light of available resources and the costs and benefits of different periods. Discounting techniques, which are used to evaluate costs and benefits over different periods, can be applied (Watkiss et al. 2019). However, this depends on what data is available and should, therefore, be evaluated by the key actor(s) in each case. A time buffer should be included to cover unexpected delays in the implementation process.

### 3.4 CAP implementation, monitoring, and evaluation

This paper focuses on the tasks and steps necessary to develop a CAP for the fishery and aquaculture sectors. The process starts with the first stakeholder meeting, where the aim is to clarify and define the scope of the fishery or aquaculture system in question. This is followed by an assessment of the risks and opportunities associated with climate change. To give the stakeholders an overview of the severity of the possible consequences to their system of climate change, forecasts are produced for the biological and social and economic impacts under different climate scenarios. The results are presented at the second stakeholder meeting, where the main findings and their implications are discussed, elaborated, and clarified. After the meeting, the risk and opportunity assessments are improved, and the revised assessments are used to develop AMs that take the vulnerability and adaptive capacity of the system into account. A comprehensive set of AMs is proposed at the third stakeholder meeting. At this meeting, the stakeholders discuss, evaluate, and agree on AMs based on their applicability to the sector and factors such as costs, resources, effectiveness, and general consensus.

When the plan is completed, the next steps are the implementation, monitoring, and evaluation of the CAP (Climate-ADAPT 2019). Implementation will rarely go exactly as planned. This may be due to inadequate follow-up or because the measures were not as appropriate as first assumed, they meet opposition from strong players, circumstances change, or other problems become more urgent. This means that monitoring and evaluation are crucial in order to learn, adapt, and ensure the effectiveness, efficiency, and equity of adaptation interventions. Through monitoring and evaluation, the implementation can be tracked, unsatisfactory progress or unexpected barriers can be identified, and additional actions or required improvements can be highlighted. It is therefore important that the stakeholders continue to participate and contribute to the monitoring and evaluation of the climate adaptation efforts. Their assessments and feedback are essential and allow course corrections that are perceived as required, relevant, and timely.

Monitoring can be conducted using a set of pre-existing and new indicators. These indicator values are evaluated against the associated outcome targets and thereby allow for the



**Fig. 5** Iterative feedback loop of CAP development

evaluation of process inputs and outputs, resources, and organizational capability, along with overall adaptive capacity (Climate-ADAPT 2019). Indicators should be measurable in the short term but should still relate to long-term outcomes. They should be quantitative if possible, but qualitative indicators can also be used. The important thing is that they allow for comparison so that they can provide evidence for additional or corrective actions. The monitoring and evaluation process should be flexible to consider the unintended and unexpected. All stakeholders with a role in the implementation of the adaptation actions need to be part of this process (EC 2013). The periodicity of monitoring and evaluation should also be determined, depending on the CAP, while ad-hoc monitoring can be conducted when new information becomes available or on the occurrence of significant events.

Learning occurs not only through the implementation, monitoring, and evaluation of a single plan but by learning from others' experiences of similar processes and by keeping abreast of recent research in the field. This implies that a CAP should be seen as a living document, which should be revisited and updated on a regular basis, e.g., every 5 years. The first three tasks that we have outlined in detail in this paper are only part of a larger cycle, also including implementation, monitoring, and evaluation, again generating iterative feedback loops over time. This is illustrated in Fig. 5.

## 4 Discussion

Climate adaptation can be complex and there is no one-size-fits-all solution. As a result, several climate adaptation guidelines, recommendations, and step-by-step approaches have been developed by international institutions (e.g., EC 2013; UKCIP 2010), and documented in the scientific literature (e.g., Smithwick et al. 2019; Wigand et al. 2017). However, in fisheries and aquaculture settings, guidance on adaptation has been minimal (Barange et al. 2018). Among the exceptions is the adaptation toolbox developed by FAO (2019) including a recent online course on climate change adaptation and mitigation in fisheries and aquaculture.<sup>7</sup> The FAO toolbox aims to facilitate and strengthen the adaptation of governments, industries,

<sup>7</sup> The course is available here: <https://elearning.fao.org/course/view.php?id=544>

fishers, and aquaculture farmers by providing guidance on the tools and methods currently available for a coordinated strategy. However, supplementary guidance and practical examples are still needed for the application of the toolbox to help stakeholders in their adaptation efforts (FAO 2019). In contrast, the CAP guidelines presented in this paper provide users with a step-by-step approach to climate adaptation in fisheries and aquaculture based on real-life case studies. AMs are developed for different categories and components of the system to make the CAP more manageable. Each step in an explicit method is provided along with examples. Hence, the guidelines can be regarded as a ready-to-go practical handbook.

Active stakeholder involvement and working partnerships have been emphasized as key principles of climate change adaptation (Climate-ADAPT 2019; EC 2013). The co-creation process helps stakeholders to consider and plan strategies toward climate adaptation in a joint effort. The multiple views of various stakeholders help improve the understanding of the issues and the selection of appropriate solutions. The frequent stakeholder meetings allow CAP developers to revisit previous steps and update the CAP when stakeholders have additional feedback, when new knowledge becomes available, or when circumstances change significantly (Ballesteros et al. 2017). The co-creation process can also promote mutual learning, foster greater trust between the participants, and create a stronger acceptance of and commitment to the CAP and implementation of the associated measures.

Nevertheless, each CAP development process will be unique. It will be influenced by who takes the initiative, who is invited to participate, who leads the process, what resources are available, the level of conflict among the participants, what decision-making authority they have, and a number of other contextual factors. In our case, the whole process was carried out as part of an EU-funded project with a consortium of research institutions and partners from industry, government, and NGOs. The conditions will often be different. It is therefore important to try to ensure that the initiative has legitimacy, that central stakeholders (e.g., industry representatives) and possible rights holders (e.g., indigenous groups) are not excluded from participating, that the work is led by good facilitators, that the co-creation process has sufficient funding, and that active work is done to reach an agreement regarding key priorities. Moreover, those who will responsible for the planned measures must be able to take action, and it must be possible to hold them accountable. The accountability can vary depending on the scales and whether CAP is voluntary or mandatory. The various stakeholder groups may have quite different interests and expectations, and they may have different perceptions of risk, urgency, and feasible solutions. A risk preference evaluation can be helpful in order to justify the participants' perception toward risk and to compare the results of different participants in a future iteration of the process. The governance level they represent can also matter. Local representatives typically bring out individual voices, while representatives at a higher organizational level tend to represent a more aggregated view. Striking a good balance between different groups of stakeholders and between the number of participants as well as the quality of participation requires careful attention. In order to bring about a constructive process, it is important to have all stakeholders involved agree on a common vocabulary, define the rules of engagement, and promote a shared vision of the planning process. In case there are conflicting interests, it is essential to try to negotiate compromises, develop win-win strategies, and create new room for maneuver.

There are some factors that make the CAP implementation different between marine fisheries and aquaculture systems. Despite discussions with stakeholders generally resulting in effective AMs, implementation of the AMs has tended to be restricted by existing policies. Marine fisheries operate on a large, often ocean basin scale, and AMs for fishery systems are



strongly influenced by political issues and governance due to the nature of shared stocks and their movements. For instance, quota allocation schemes are normally not responsive to distributional changes (Fernandes and Fallon 2020), causing choking effects (Baudron and Fernandes 2015), affecting species composition and the structure of trophic interactions, and resulting in large-scale variation in the food web structure along environmental gradients (Kortsch et al. 2019). Political conflicts and current quota allocation schemes were also evaluated as a major obstacle to an efficient implementation of the CAP in the fisheries cases tested (Table 1). In the West of Scotland fisheries, the principle of “relative stability” prevented the use of flexible quota allocations as an AM to changing species distributions. It was therefore evident that in order to develop an effective adaptation plan for fisheries, existing marine policy frameworks and political issues would first have to be resolved and adapted. This is commonly beyond the scope of the CAP and outside the capacity of the CAP consortium and thereby impedes the ability of the fisheries industry to take on any larger adaptation efforts itself. Nevertheless, the CAP process can help stakeholders to identify these main political barriers and offers solutions in the form of policy recommendations. As a result, CAPs developed for marine fishery systems will be most valuable if they address climate change adaptation at the MS or EU level.

Aquaculture systems generally operate on a much smaller scale than fisheries and are regulated through various local, national, and international legislations. It is therefore usually easier for the aquaculture industry to initiate and implement climate adaptation measures. In the aquaculture case studies (Table 1), the industry demonstrated great interest and willingness to adapt, as farmers have the ability to decide on their own adaptation planning and implementation, but also because many companies recognize that climate adaptation is in their own economic interest. Adaptation measures can be implemented by individual farmers through simple adjustments in, for example, infrastructure and practices, or the introduction of novel technology. In other words, CAP for an aquaculture system could already be effective at the local or national level.

Furthermore, aquaculture legislation is generally more up-to-date, as the aquaculture sector lacks the long history and tradition of the fisheries sector. No specific legislation for adaptation to climate change was observed in the aquaculture case studies tested; nevertheless, the existing regulations largely cover the challenges identified in the face of climate change. The challenge is that existing legislation is not organized in a coherent regulatory framework, but rather in the form of a list of complex regulations that often make the implementation of AMs cumbersome. Therefore, it is necessary to simplify the existing regulations into a more comprehensive and easy-to-follow the framework. This framework should also explicitly incorporate AMs to climate change, but without the need to create standalone legislation, instead of reinforcing that which already exists.

To be effective, CAPs should be aligned with strategy and policy processes that are currently in development, under evaluation, and/or revision. In fisheries, the scope and timelines of CAPs could be aligned with the Marine Strategy Framework Directive and the Common Fisheries Policy. In aquaculture, The European Commission is revising the “Strategic Guidelines for the sustainable development of EU aquaculture” that will include climate adaptation aspects. This document will guide the MSs when revising their Multi-Annual National Plans (MANPs) for their aquaculture development. Our guidelines and the CWA 17518:2020 provide additional support to the revision of the country-specific MANPs to enable and increase climate adaptation capacity.

Finally, it is important to have in mind that potential limitations always exist when planning for climate change adaptation (IPCC 2014). This is due to the nature of uncertainties and remaining knowledge gaps to climate change (Owen 2020). Yet, these are limitations inherent to climate adaptation rather than the presented CAP guidelines. Therefore, when developing CAPs for a specific system using the guidelines, one should consider these limitations during the scoping and planning of any adaptation efforts.

## 5 Conclusions

The guidelines presented in this paper provide a practical and concrete, step-by-step approach to making climate adaptation plans in the fishery and aquaculture systems. The guidelines focus on a co-creation approach that allows stakeholders to effectively collaborate and work in partnership. Thus, the guidelines promote a systematic, time bound, transparent, and inclusive process for climate adaptation. The guidelines have been tested and prototyped through their application in seven fisheries and aquaculture case studies across Europe. Through this process, the stakeholders of the respective case studies have validated their practical applicability. The guidelines are transferable to different geographical areas and to different scales, from single species to ecosystem levels. The guidelines are based on the CWA voluntary standard, which has undergone thorough public review and revision throughout the standardization process. The CAP development process follows the same steps for fisheries and aquaculture but differs in terms of scale and scope. For aquaculture, CAPs can be developed from farm, municipality, or the local scale to the national and EU scale. Fisheries, however, are often more complex due to the nature of shared resources and their strong governance and political components. Hence, CAPs for fisheries will likely have to consider Member State and EU level adaptation measures. When a CAP is implemented, it should be monitored, evaluated, and regularly updated to ensure its effectiveness, efficiency, and equity.

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## Declaration

**Conflict of interest** The authors declare no conflict of interest.

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